Renewable and Sustainable Energy Reviews 16 (2012) 4445–4460

Contents lists available at SciVerse ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

A review on the renewable energy development in Algeria: Current perspective, energy scenario and sustainability issues

A. Boudghene Stambouli [a,*], Z. Khiat [b], S. Flazi [b], Y. Kitamura [c]

[a] Electronics Department, University of Sciences and Technology of Oran, BP 1505, El M'Naouer, Oran 31000, Algeria
[b] Electrical Department, University of Sciences and Technology of Oran, BP 1505, El M'Naouer, Oran 31000, Algeria
[c] Institute for Arab Economies Research, Japan

ARTICLE INFO

Article history:
Received 21 January 2012
Received in revised form
7 April 2012
Accepted 18 April 2012
Available online 20 June 2012

Keywords:
Solar
Wind
Hydro
Biomass
Geothermal
Sustainability

ABSTRACT

The quality of life and safeness of the present and future generations are strongly intertwined with the availability of energy sources and the sustainability of the energy infrastructure. Energy consumption in developed countries grows at a rate of approximately 1% per year, and that of developing countries, 5% per year (Muneer et al., 2005 [1]). Present reserves of oil and natural gas can only cover consumption at this rate for the next 50 years in the case of oil, and for the next 70 years in the case of natural gas. Therefore, one of the fundamental priorities for a country such as Algeria is to use several renewable energies (RE) sources and environmentally friendly energy conversion technologies. Algeria is endowed with large reserves of energy sources, mainly hydrocarbons and a considerable potential for the utilisation of RE sources especially with respect to solar energy. Algeria has the potential to be one of the major contributors in solar energy and become a role model to other countries in the world. RE are now one of the major elements of Algeria's energy policy and in view of boosting the national effort in terms of RE beyond 2011, Algeria has developed a national programme for the period 2011–2030 to promote concrete actions in the fields of energy efficiency and RE in line with the approach adopted by the government on February 3, 2011. Besides, it confirms Algerian's ambition to become an international hub for industrial and energy production and exportation in the solar sector. With this in mind, along with the environmental responsibility issues, public awareness gradually increased over the last seven years and alternative energy resources have become a new area of interest. As a tangible target, the Ministry of Energy and Mines (MEM) strategic plan aims to reach a 40% share of RE (mainly solar) in electric energy production by 2030. The various future projects are all factors that will undoubtedly give Algeria an important role in the implementation of RE technology in North Africa, the capacity for providing sustainable supply of cost-effective electricity from RE sources for the needs of the population, and the possibility of even exporting 10,000 MW to neighbouring and European market. This paper provides a detailed analysis of the existing renewable energy sector and a forecast for demand growth, additional capacity, investment requirements and Algeria's ambitious objectives of use of RE and environment protection. The paper also discusses the current energy scenario and explores the alternative energy like solar and wind to ensure energy security supply, reliability, greater efficiency in energy conversion, transmission and utilisation. Particular attention is paid to Algeria's global and sustainable solutions of the environmental challenges and the problems of conservation of fossil energy resources under the clean development mechanism (CDM) structure. The report also provides a detailed analysis of the existing renewable energy sector and a forecast for demand growth, additional capacity, and investment requirements

Contents

1. Introduction 4446
2. Algeria's energy sector overview 4446

* Corresponding author. Tel./fax: +213 41 56 03 01.
E-mail addresses: stambouli@ssb-foundation.com (A.B. Stambouli), kitamura@arab-economies.com (Y. Kitamura).

1364-0321/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.rser.2012.04.031

3. Renewable energies availability and potential in Algeria . . . 4449
3.1. Solar energy . . . 4449
3.1.1. PV Solar energy . . . 4450
3.1.2. Thermal solar energy . . . 4451
3.2. Wind energy . . . 4452
3.3. PV and wind installations . . . 4453
3.4. Solar and wind current and future realisations . . . 4453
3.5. Hydroenergy . . . 4454
3.6. Geothermic energy . . . 4454
3.7. Biomass energy . . . 4454
4. RE and energy efficiency programme . . . 4455
4.1. RE programme . . . 4455
4.1.1. PV solar energy programme . . . 4456
4.1.2. Thermal solar energy programme . . . 4456
4.1.3. Wind energy programme . . . 4457
4.2. Energy efficiency programme . . . 4457
4.2.1. Energy efficiency programme components . . . 4457
5. Clean development mechanism in Algeria . . . 4458
6. Conclusion and recommendations . . . 4459
References . . . 4459

1. Introduction

Energy resources are not evenly distributed across the globe and the global energy consumption is likely to grow faster than the increase in the population [1]. The world will continue to depend on fossil fuels since over 80% of world's primary energy comes from fossil fuels which have detrimental impacts on the environment and produce the heat trapping green house gases (GHG) carbon dioxide as the products of combustion and methane as an inadvertent product of drilling, mining and transporting those fuels. The fuel consumption was growing from 6630 million tons of oil equivalent (Mtoe) in 1980 to almost double of the energy consumption which had reach 11,295 Mtoe in 2008 [2]. World total energy supply in 2000 and 2009 is also estimated and shown in Table 1 [3].

According to the estimation done by the International Energy Agency (IEA), a 53% increase in global energy consumption is foreseen by 2030, energy security is becoming a serious issue as fossil fuels are non-RE and will deplete eventually in near future. In addition, the world's oil resources will peak within a few decades to come (80 years at the most), and in the search for other sustainable alternatives to mitigate some political, economic and environmental currently associated with the heavy reliance on fossil fuel, it is inevitable that the world is heading towards RE and new energy (hydrogen) economy by promoting clean energy technologies, pursuing energy efficiency and developing RE forms which are three orders of magnitude larger than current global energy use. Algeria is enjoying enormous potential of RE namely solar, wind, geothermal and biomass and hoping to increase its RE status by generating as much electricity from green sources as it currently produces from its natural gas power plants by 2020. Algeria has large potential for solar electricity production since it is located in the so-called Sunbelt (Fig. 1) [4].

Table 1
World total energy supply in 2000 and 2009.

Source	Energy class (%)	
	2000	2009
Fossil Fuels	80	66
Renewables	13	26
Nuclear	7	8

The government is planning to start a new RE development plan [5], according to Algeria's Energy Minister Youcef Yousfi who said, "It's a huge program and a huge challenge. The government will work alongside and assist operators in its implementation".

Although Algeria has begun a few initiatives to promote sustainable energy, generating as much energy from RE as its current production of natural gas is a pipedream, some specific factors place Algeria in a perfect position to take a leading role as a European energy supplier and future provider of clean energy. The population distribution in Algeria also shows that there is a great potential market for RE, among which solar energy should be highlighted because of its homogeneous presence throughout the entire region [6].

Moreover, economic development and diversification, population growth, the huge hydrocarbon endowment, the vast potential for solar energy could also drive the development and implementation of a regional vision for hydrogen economy.

2. Algeria's energy sector overview

Its large oil and gas reserves as well as its mere size of 2,381,741 km^2 and 34.8 million inhabitants (14.5 inhabitant/km^2) make Algeria an important player in northern Africa as well as on international level. Algeria is one of the top 10 economies in Africa and plays a central role in the energy world, as it is a major producer and exporter of oil and natural gas. The country is working on its own and with several major oil companies (BP, Anadarko Petroleum, and Talisman Energy) [7]. Algeria sits on 12.2 billion barrels of proved oil reserves, and 4.51 trillion cubic metres on its proven natural gas (NG) reserves, according to the Oil and Gas Journal [8]. In addition as hydrocarbons producer, Algeria is also enjoying enormous potential of RE namely solar, wind, geothermal and biomass. High population growth, rapid urbanisation and accelerated development present major challenges in the struggle to meet increasing electricity and domestic water demands (water scarcity and dependence on underground and non conventional sources of water such as desalination). The coupling of RE and desalination systems, for example, holds great promise for increasing water supply in the region [9,10].

In 2008, Algeria produced approximately 1.4 million barrels per day (mbl/d) of crude oil, of which 85% was exported, and 86.5 billion cubic metres (bcm) of natural gas, of which 70% was exported, mostly to Europe [11]. In 2009, sixteen oil and gas

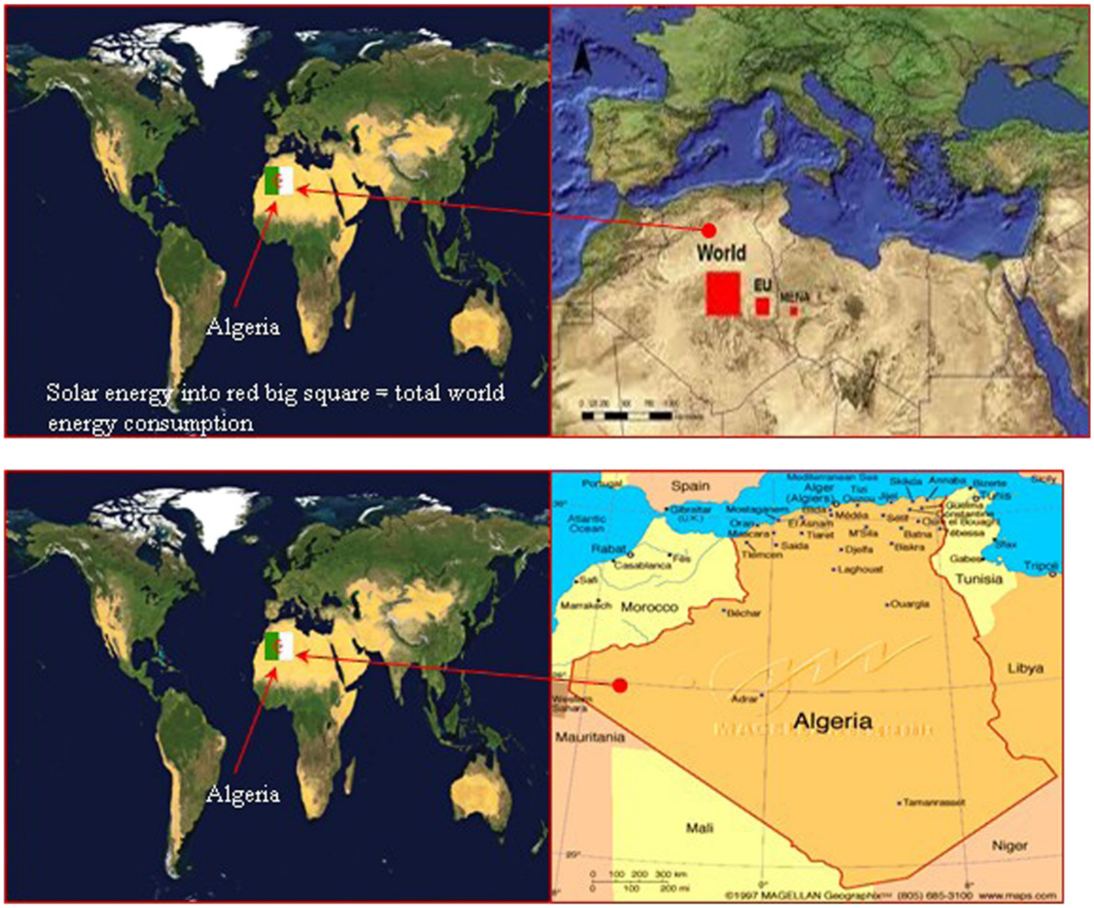


Fig. 1. Solar suitable sites in the world, Algeria situated in the solar belt of the middle of the world.

discoveries were made in the country and during that year, Algeria's oil production totalled 2.13 mbl/d of oil liquids, consisting of 1.33 mbl/d of crude oil, 457,000 barrels per day of condensate and 345,000 barrels per day of NG liquids [12]. The country's three major basins are the Hassi Messaoud, Berkine and Hassi R'mel basins. Algeria is the fourth largest crude producer in Africa [13] and the sixth largest natural gas producer in the world (after Russia, the United States, Canada, Iran and Norway). NG has become an increasingly valuable resource and a global commodity. Estimates of NG reserves in Algeria vary quite dramatically depending on the source. Sonatrach, in 2004 estimates Algerian reserves at 4.52×10^{12} m^3, which implies a lifetime of 62.2 years, compared with an expected 61.9 years globally [14].

Oil and gas export revenues account for more than 95% of Algeria's total export revenues, around 70% of total fiscal revenues, and 40% of gross domestic product (GDP).

Compared to other developing countries with a similar GDP, Algeria's energy consumption is high: 1.2 t of oil equivalent (toe) and 1000 kWh/year of electricity per capita. However, these figures include self-consumption and losses in the energy sector due to liquefied NG (LNG) exports. In 2008, Algeria was the world's fourth-largest supplier of LNG, delivering 10% of the gas consumed by Europe. The share of oil in the country's overall consumption fell from 40% in 1990 to 34% in 2007; the share of gas increased from 57% to 64%. In industry, gas accounts for nearly 53% of final consumption. Gas consumption also increased substantially in the residential sector, and in 2007 accounted for 46% of final energy consumption. Not much changed in 2009, according to Market Research [15], the dominant fuel in 2009 was NG, accounting for an estimated 61.7% of the primary energy demand. This was followed by oil at 36.2%, and coal at 1.8%. The country is connected to Europe through two gas pipelines, to Italy via Tunisia, and to Spain via Morocco. Three additional pipelines are in development: Medgaz, linking directly Algeria to Spain, Galsi, from Algeria to Sardinia and the Italian mainland, and Trans-Saharan, from Nigeria to Algeria. This pipeline would make it possible for Nigeria to export part of its production to Europe through Algeria. Algeria also has four LNG plants, with a fifth one in development (LNG accounts for one-third of Algeria's gas exports) [16,17]. The hydrocarbon sector is dominated by Sonatrach, a state-owned company, whose objective is to increase the gas export capacity form the current 65 bcm per year, to 85 bcm per year around 2010–2012, and 100 bcm per year by 2015 [12,15,17,18]. Moreover, Algeria's oil and gas revenues have already increased by a quarter above 2009 levels, hitting $55.7bn in 2010; but this was on a reduced volume of fossil fuel exports. The country's government is now hoping to generate revenue from the export of alternative energy according to Minister Yousfi of MEM [19].

The electricity market in Algeria is very important with a growth rate exceeding 6% [6]. Sonelgaz is the state-owned electricity and downstream gas utility. Total installed power generation capacity amounts to 10 GW, approximately 50% of which are open cycle gas turbines, 12% combined cycle gas turbines, 35% conventional steam turbines and 3% hydraulic. Over 98% of the electricity production is based on natural gas, the balance originating from fuel oil/diesel and hydropower. Electricity prices are low in Algeria, especially for residential customers, mainly due to low internal prices for natural gas: around 6

USc/kWh for residential customers and a little over 3 USc/kWh for industrial users [20].

Recently the covering capacity for electricity installations network amounts the rate of 98% in which more than 80% is being in the north of the country. Algeria has over 225,309 km of power lines (Fig. 2), serving almost the entire population with plans to increase the size of the network by 5% in coming years in order to reach isolated rural communities and hydrocarbon developments in the Sahara desert [21,22].

To keep up with electricity demand growth, 8–10 GW of new power generating capacity are expected to be built by 2015, about 70% of which would be built by independent power producers (IPPs).

The Algerian government is now looking to reduce the economy's dependence on the hydrocarbon sector, which represents 98% of the country's hard currency income. Algeria is called to exert a great effort to bring its economy out of dependence on oil and to diversify its resources in order to avoid being hostage to the fluctuation of oil prices in the international markets, said President Abdelaziz Bouteflika [23,24]. He also stated that the promotion of RE has to be the clear target for the country, and that environmental issues need to be addressed.

Current and future challenges to Algeria such as high population growth, rapid urbanisation, accelerated development, rising energy demand, water scarcity, might intensify as Algeria's population keeps increasing at 1.5–3% per year [25,26] so that we are doubling our population every 40 years (Fig. 3).

The consumption of energy at the national level is increasing year after year due to demographic and urban development, in addition to economic development in constant progression. In a context of economic recovery, energy demand could double by the year 2020 (60 MTOE, even 70 million MTOE) by increasing uses of energy and economic activities. The energy consumption is likely to grow faster than the increase in the population. These impacts, requiring careful consideration, present major challenges in the struggle to meet increasing electricity and domestic water demands. The National Energy Efficiency Agency (NEEA) and the Promotion and Rationalisation of Energy Use Agency (APRUE) expect energy consumption to increase at an annual growth rate of about 3.5%. The demand for electricity will be particularly high due to urbanisation, an increasing standard of living and development of service sector.

The coupling of RE and desalination systems, for example, holds great promise for increasing water supply in the region since the rapid increase in water demand, the drought in two decades in

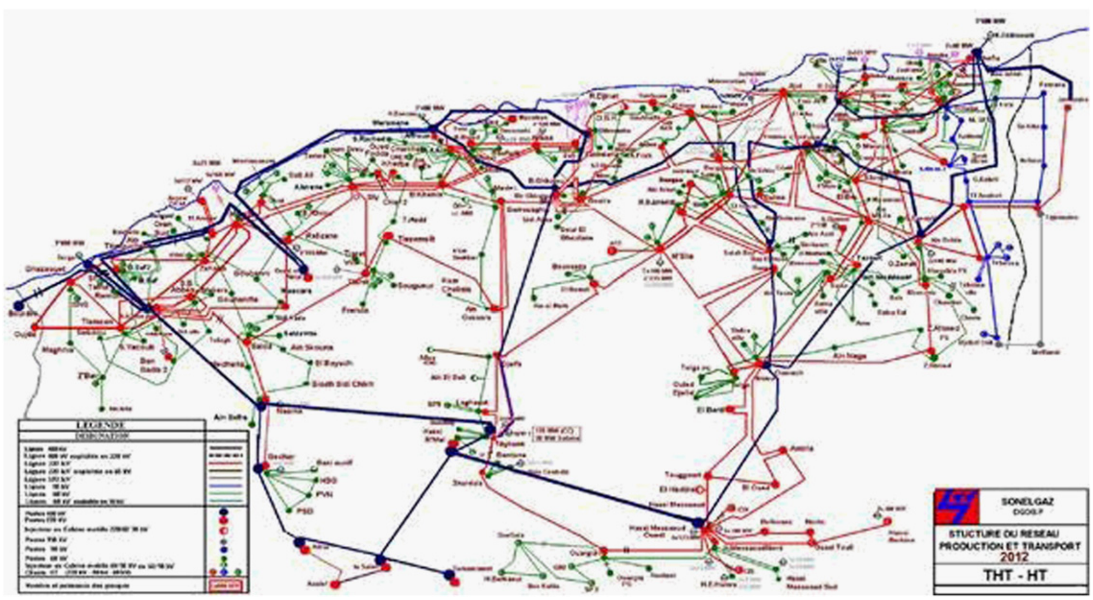


Fig. 2. Algerian electricity grid. Sonelgaz, 2009.

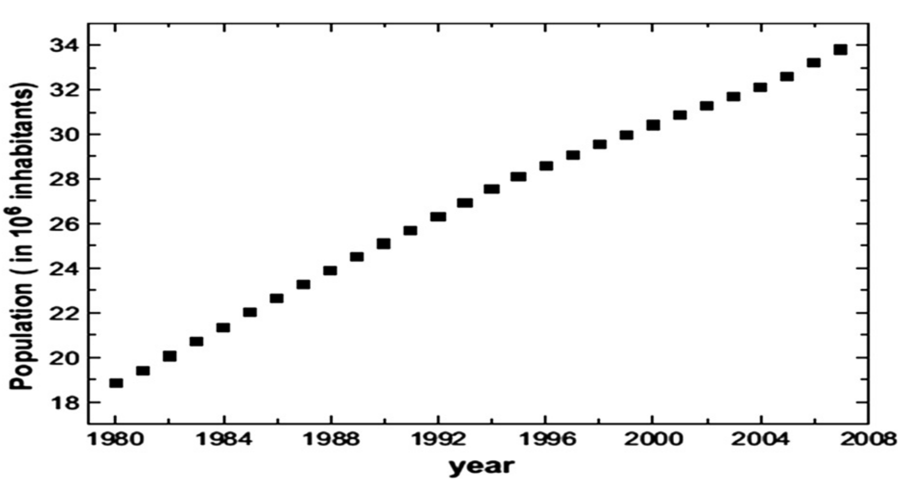


Fig. 3. Evolution of the Algerian population 1980–2008.

Algeria, has meant that the Algerian Energy Company (AEC) has focused in recent years on the activity "Desalination of sea water". In recent years it has developed an ambitious programme of thirteen projects which two are already in operation, with a total capacity of 2,260,000 m^3/day, one of the largest capacities in the world [27,28].

Algeria is now undoubtedly perceived in various aspects as front-runner in energy matter. The 150 MW Hassi R'mel solar plant, an important source of experience in solar energy techniques by NEAL (New Energy of Algeria), as well as various RE projects financed and promoted by national and private industry [28,29] are one example of Algeria's declared will to invest and move onto a more sustainable energy path. Algeria is putting into place plans to increase renewable energy capacity over the next 20 years and set renewable energy targets to be met by 2030 that range up to 40% of the total energy mix. The targets could see the region's RE capacity rise to 22,000 MW to reflect its commitment to the governmental decree of March 2004 relative to the introduction of incentives for electricity production from RE plants, including a feed-in tariff and the law No. 04–09 of August 14, 2004 relative to the promotion of the RE sources within the framework of sustainable developments of the country [30].

3. Renewable energies availability and potential in Algeria

Nowadays, almost in every part of the world, RE initiatives are taking place, and to be effective, a number of key political actions are required; put into practice the best support schemes, remove barriers and enforce legal enforceable mechanisms. Among the other impacts requiring careful consideration are the relationships between energy systems and social issues, political responsibility, economic development and environment protection. In particular, strategies should emerge from the manner in which energy can contribute to the solution of social problems. Despite high growth rates, RE still represents only a small part of today's global energy picture (Fig. 4, total values include estimates for undisclosed deals) [31].

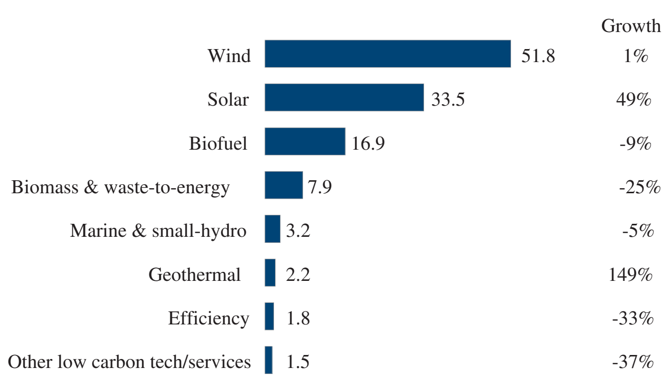


Fig. 4. Global trends in sustainable energy investment 2009.

Algeria is currently adopting the four fuel diversification strategy energy mix implemented in the year 1998 when government launched the Special Funds for Development of the South Areas of the Sahara. This programme was the first step to encourage and intensify the utilisation of RE, mainly solar, in power generation. According to this strategy, the energy mix in Algeria is contributed by five main sources, namely natural gas, oil, hydro, solar and wind [32]. Algeria has strong potential for solar, and the International Energy Agency estimates that the country has enough land with strong sunshine to produce 162 TWh of electricity [33].

3.1. Solar energy

Solar energy represents an abundant resource and the most promising source of clean, RE which theoretically could supply the world's energy demand and therefore, solve the world's energy problems. The capture of even 1% of this power would supply more than the world's power needs [34,35]. The climatic conditions in Algeria are favourable for the development of solar energy due to the abundant sunshine throughout the year, especially in the Sahara region, broadly confirmed by the World Energy Council (WEC) [36] and shown in Fig. 5 and Table 2 [37–41]. The region has amongst the world's best production conditions for solar power: abundant sunshine, low humidity and precipitation, and plenty of unused flat land close to road networks and transmission grids. Due to these conditions, the potential for power generation is enormous compared to regional and global energy demands—roughly 10% of the Algerian Sahara desert could meet the EU demand [42].

The insulation time over the quasi-totality of the national territory exceeds 3000 h annually and may reach 3900 h in high

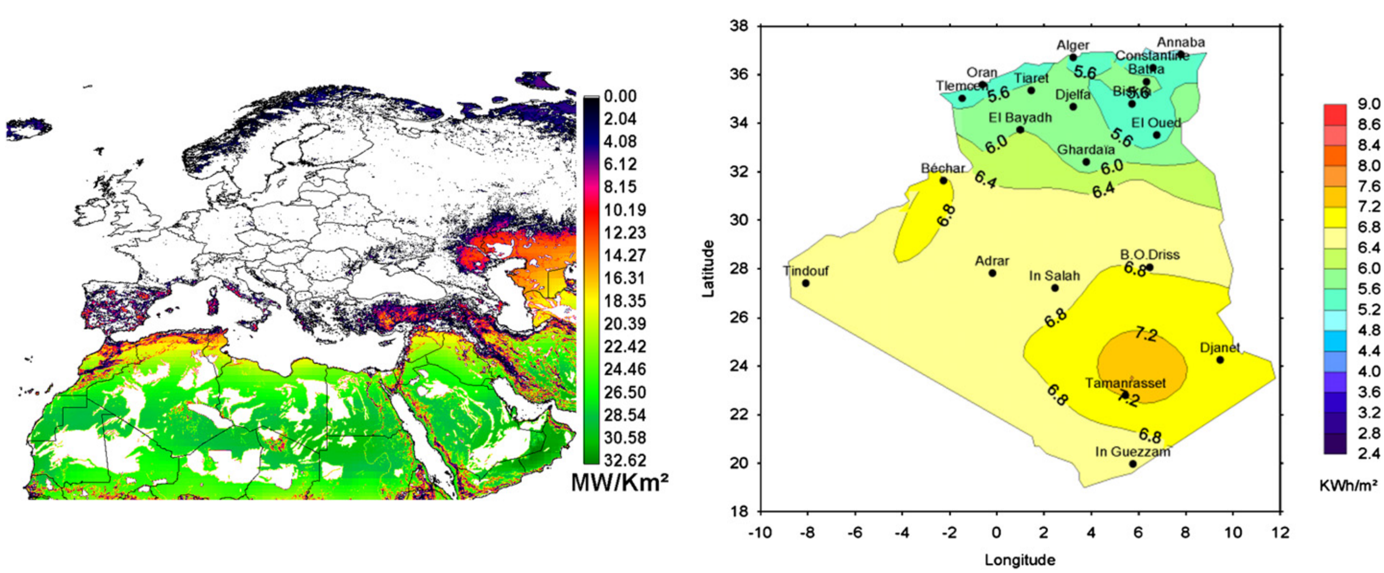


Fig. 5. Potential sites for solar electricity supply in the North Africa region and example of the overall daily exposure received (in kWh/m^2/day) in Algeria.

Table 2
Solar potential in Algeria.

Areas	Coastal area	High plains	Sahara	Total
Surface (%)	4	10	86	100
Area (km^2)	95,270	238,174	2,048,297	2,381,741
Mean daily sunshine duration (h)	7.26	8.22	9.59	
Average duration of sunshine (h/year)	2650	3000	3500	
Received average energy (kWh/m^2/year)	1700	1900	2650	
Solar daily energy density (kWh/m^2)	4.66	5.21	7.26	
Potential daily energy (TWh)	443.96	1240.89	14,870.63	16,555.48

plains and Sahara. With this huge quantity of sunshine per year, Algeria is one of the countries with the highest solar radiation levels in the world. The data presented by the Centre for Development of Renewable Energies (CDER) and MEM is supported by WEC that stay in the same range. This solar potential exceeds the 6 billion GWh/year. The economic potential for solar energy generation in Algeria has been assessed by the German Aerospace Centre (DLR) and the CDER, mainly from satellite imaging and further processing. The derived economic potential data are gathered in the RE guide report by the MEM [37,43] and estimated at 169,440 TWh/year for thermal solar (TS) and more than 13.9 TWh/year for photovoltaic (PV). There is a large difference between thermal and PV solar economic potential. This is somewhat distorting because at the time when the assessments of potentials were made, the cost difference and expected cost differences in the near future were very large. However, this situation has changed significantly during the last three years as PV technology prices decreased sharply; hence, investment costs for power plant investors have decreased. The effect is an increase in the economically utilisable potential on the PV side, which will lead to a decrease of thermal solar potential.

To reach recently set RE targets; the Algerian government is investing large sums of money in solar power. With its close proximity to Europe and the advent of the 40% of Algeria's power coming from RE sources by 2030, the reported 60 projects for RE pegged to take place between now and 2030, DESERTEC Industrial Initiative, Sahara Solar Breeder project [44], in addition to Algeria's existing renewable plans, the future export potential of the region is high. This will certainly make the Maghreb region (Morocco, Algeria and Tunisia) one of the most attractive RE investment destinations in the world. In addition, many companies are setting up offices and manufacturing facilities in the region and local holding companies are moving into the manufacture of solar technologies and components. It is very encouraging to see these emerging nations embrace clean energy. Algeria will be split almost 50/50 between traditional and renewable energy investment and has announced an investment of more than $20 billion in renewable electricity over the next 20 years.

Solar electricity devices are often referred to as PV or concentrating solar power (CSP). PV is considered as one of the key technologies that are at the heart of the energy technology revolution because they can make the largest contributions to reducing greenhouse gas emissions [45–49].

3.1.1. PV Solar energy

PV is an elegant means of producing electricity on site, directly from the sun without concern for fuel supply or environmental impact. Solar power is produced silently with minimum maintenance, no pollution and no depletion of resources. One of the strengths of PV is to be found in its decentralised applications and cutting out the cost of transporting the energy. This is particularly true for supplying isolated consumers in areas of low population density, where the demand consists essentially in satisfying basic energy requirements (light, refrigeration, pumps, television and radio). Other notable characteristics of PV are:

- modular design enabling it to be extended according to need;
- the possibility of developing small businesses in areas of low economic development;
- protection of the environment;
- limited capital assets, capable of being used flexibly and in a decentralised way, and of being moved about over longer periods of time.

Solar PV energy, as exceedingly versatile system, is being developed in Algeria mainly for 6 applications: domestic uses, water pumping, refrigeration, village electrification in situations where no electricity is available, lighting, and telecommunication. Due to the high initial cost of PV system, Algeria does not have any local PV manufacturer. All the PV modules are imported from foreign countries like Germany, Spain and Japan, hence causing the cost of PV systems to be very high. Algeria appears keen to attract foreign investment for its renewable projects, announcing on February 7, 2011 that it has awarded German manufacturer Centrotherm Kinetics a € 300 m (DA, Algerian Dinars, 29.8 bn) to construct an almost fully integrated solar module factory in Algeria. This factory will impress by covering the entire solar value chain, ranging from ingot production and solar cell manufacturing through to solar module end-products, although it will not include the production of silicon as a raw material [50,51]. The high degree of integration in the production of solar wafers, cells and modules allows low production costs to be achieved, thereby resulting in high-quality modules at competitive prices. The first high-performance modules should be produced by 2014 at the plant, which is to be constructed at Rouiba, 30 km east of the capital Algiers. These modules are primarily intended to supply the domestic market. The largest solar module factory in the African continent's first largest country will deliver an annual production capacity of around 116–120 MW_p and is to be constructed on a land area of around 43,000 m^2. The cost of the Watt-peak proposed by this PV industry world leader is 168.4 DA.

The solar pyramid, proposed by Kurokawa for the desert of Gobi in Asia [52], shows in the case of the Algerian Sahara (Fig. 6) [33] that with 50% of the space factor, 10% of the system energy efficiency and a 14% PV module coverage, the amount of solar electricity produced exceeds 605×10^{18} J/year (note that the world primary energy supply in 2002 was 379×10^{18} J/year). This means that it would be feasible to consider solar energy as a potential energy source for different applications in the form of individual PV solar panels or systems [38]. It is estimated that there are more than 900 homes using PV system at the moment in eighteen (18) villages of the great south (provinces of Adrar, Illizi, Tindouf and Tamanrasset) [29,43]. This first phase programme of PV project was implemented under the initiatives of the MEM in 1998 and entirely financed by the Special Funds for Development of the South Areas. This project has given the necessary beginning

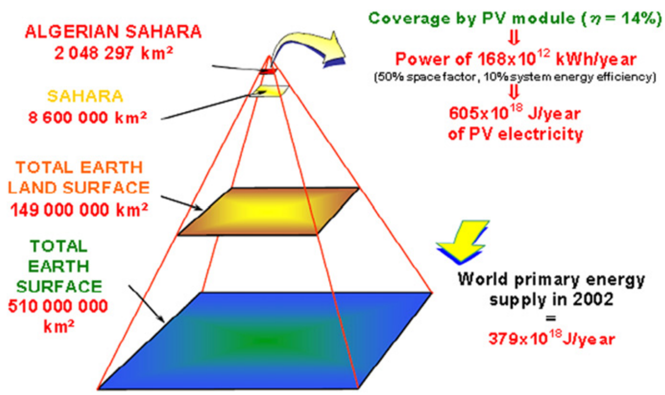


Fig. 6. Solar pyramid: the Algerian desert, dead space can be a treasure island of energy used by humanity.

Table 3
Second phase new installation projects.

Province	Village	Homes by unit	Distance from the grid (km)
Tamanrasset	Abdnizi	3	270
	Ait Ouklan	20	150
	In Azarou	26	90
	Tigannouine	70	70
	Idikel	25	50
	Tit Loukten	15	44
	Ilamane	20	25
	Tensou	20	120
El-Oued	El Ghanemi	40	45
	El Maklia	60	40
M'Sila	Zbiret	100	50
Illizi	Ikabren Tarat	20	70
	Arrikine	25	140
	Issendiline	12	90
	Dider	20	50
Ghardaia	Hassi Ghanem	72	60
Total		**548**	

for the effective and efficient transfer of technology in the field of PV power generation in Algeria.

The solar applications, by implanting PV power plants, are an extension of already existing diesel power stations in isolated areas and are limited to electrification, pumping, telecommunication, public lighting and small refrigeration systems. Sonelgaz have gone down the solar route for these 18 villages in the rural electrification programme with the aim of kick-starting the use of renewables and particularly PV energy [53].

The rural electrification second phase project will be approached with the same way as certain similar projects developed in the neighbouring countries. The role of Sonelgaz would be in this case a provision of a financial engineering service. It is a question, for the populations non-connected to the network, of being able to profit from photovoltaic systems of production of electricity for the domestic needs and the pumping of water. The concerned new sixteen (16) villages which will benefit from these new installations (starting 2012) are illustrated in Table 3 [37]. The Algerian Regulatory Commission of Electricity and Gas (CREG, a filial of Sonelgaz) has presented a short term plan to tap its large potential for PV. This is included in the electricity market and security of supply strategy of Sonelgaz with an overall target to generate at least 5% electricity from PV by 2017. Table 4 provides an overview of PV energy targets projects in Algeria up to 2017 (by CREG) [54].

Table 4
PV realisations and perspectives

Year	2009	2010	2011	2012	2013	2014	2015	2016	2017
Power in MW_p	0.51	1.23	1.65	2.21	2.85	3.21	3.80	4.22	5.22

Table 5
List of new CSP projects in pipeline (proposed generation projects in the Algerian investment plan).

Location	CSP capacity (MW)	Total capacity (MW)	Est. cost (10^6US$)	CTF contribution (10^6US$)[a]
Megahir	80	400	322	58.4
Naama	70	400	285	51.1
Hassi R'mel II	70	400	285	51.1
Total	**220**	**1200**	**892**	**160.6**

[a] CTF: Clean Technology Fund.

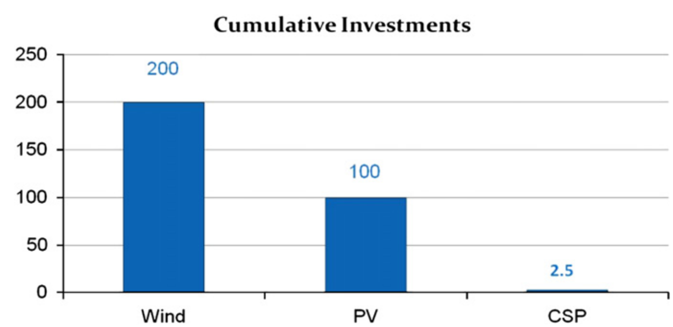


Fig. 7. Global investments in RE Technologies (US$ billion).

To meet this target, the current promotion mechanism for PV source of electricity relies on feed-in tariffs that are set, in the new RE Law, to facilitate expanding the deployment of this type of RE.

This developing strategy has been elaborated to promote the dissemination of RE on sites where they are profitable compared to classical energies and to guide scientific research efforts in order to allow generalisation of RE via mass production. The aims to be achieved consist of the contribution to a conservative policy for hydrocarbons both by increasing the RE share within the national energy balance and by improving the living conditions of isolated communities. This operation would allow on one hand to supply isolated area with electricity and on the other hand to collect information about:

- Equipment behaviour in Saharan environment.
- Matching the systems with the electricity supply.
- Maintenance organisation and management.
- Technical–economic system optimisation.

3.1.2. Thermal solar energy

Thermal solar energy applications are mainly oriented towards CSP, as a large-scale, proven technology for generating energy using the power of the sun, and domestic hot water systems. At the global level, cumulative investment in CSP is still very small compared to investment in other renewable energy technologies as shown in Fig. 7 [23].

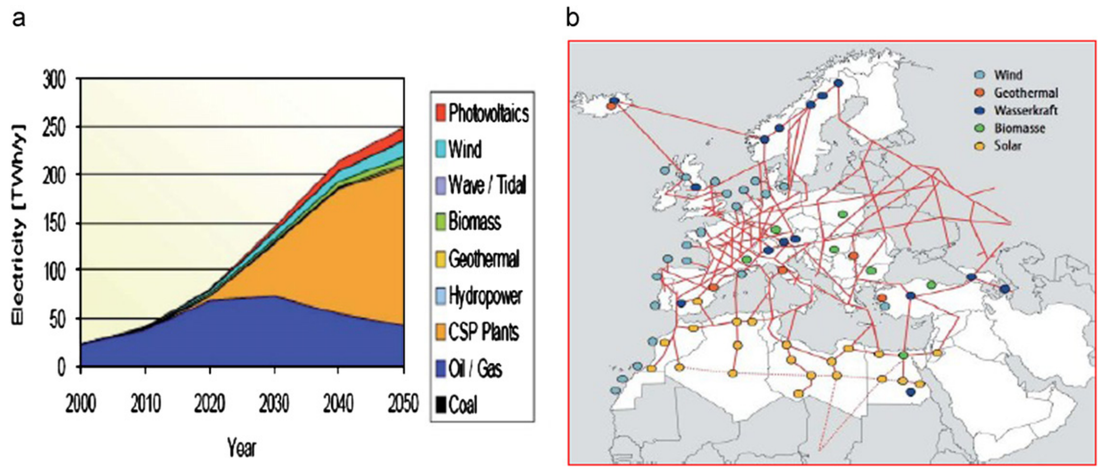


Fig. 8. (a) Left: Electricity supply scenario for Algeria. (b) Right: HVDC backbone grid integrating different type of RE.

The long-term goal of Algeria's RE achievement is to be met primarily from the CSP which would make it among the world's most ambitious CSP programmes. Through a March 2004 decree and the recent national programme to promote concrete actions in the fields of energy efficiency and RE, the Government also introduced incentives for electricity production from RE plants, including a feed-in tariff.

A first Integrated Solar and Combined Cycle (ISCC) plant has been currently inaugurated at Hassi R'mel. This project will give Algeria valuable experience in the development, construction and operation of an ISCC:

- *Location*: Hassi R'mel, where Sonatrach operates Algeria's largest gas field.
- *Technology*: hybrid parabolic trough/gas-fired combined cycle.
- *Capacity*: 25 MW CSP, 150 MW in total.
- *Area*: 152 ha.
- *Cost*: € 315 million.
- *Commissioning*: August 2010.
- *EPC contractor*: Abengoa.
- *Offtaker*: Sonatrach.

Three further hybrid units are to be completed by 2015, with 70–80 MW CSP capacity for each one of them. They will be scale-ups of Hassi R'mel, and are part of the government's plan to develop renewable energy production and exports in Algeria. Table 5 lists the new CSP proposed generation projects in the Algerian investment plan under MENA CSP scale-up programme.

In October 2009, the World Bank (WB) announced the Clean Technology Fund (CTF) Investment Plan that proposed co-financing of 13 solar thermal power plants in selected five countries in the MENA: Algeria, Egypt, Jordan, Morocco and Tunisia, corresponding to an investment volume of US$5.5bn. It is envisaged to accelerate global deployment of CSP by investing in the CSP expansion programmes [23]. The proposed CTF supported programme will therefore almost triple global investment in the technology.

With a scheduled accumulated CSP capacity of 220 MW, the three projects envisaged for Algeria would fit well into the national renewable plan.

Two options are being considered for the first project, which will be located in Meghaïr, in the southeast part of Algeria. Both would include a 270–280 ha solar island using parabolic trough:

- *Option 1*: power production only, total capacity 400 MW, of which 70 MW generated from CSP.
- *Option 2*: integrated desalination/power production, total capacity 480 MW, of which 80 MW CSP (the plant would treat local brackish water).

The plant would also serve the domestic market. It could be either public or Public Private Partnership (PPP).

The second and third projects would be technically identical to Meghaïr with option 1: pure ISCC, total capacity 400 MW with 70 MW parabolic trough. They would be located, respectively in Naama, in southwest of Algeria and Hassi R'mel, adjacent to the plant currently in operation.

The analysis, by DLR and CDER, stated a theoretical CSP potential of around 170,000 TWh/yr, providing that the country could easily become self-sufficient using RE only. The current national electricity demand is 35 TWh/yr [54]. The study also drafted a roadmap for a supply situation until 2050, where more that 80% of Algeria's electricity demand is covered by RE. Fig. 8(a) shows that in 2050, most of the RE supply would be covered by CSP plants [55,56]. In the scenario, a total capacity of 30 GW and an annual production of 166 TWh are featured. In DLR's scenario for Algeria, the electricity costs of CSP plant will range at levels below the 8 €cent/kWh [55].

DLR also released the so-called TRANS-CSP which investigates the High Voltage Direct Current (HVDC) transmission of CSP generated electricity from MENA to Europe as depicted in Fig. 8(b) [56].

3.2. Wind energy

Wind energy is considered as a green power technology for having minor impacts on the environment. Wind energy plants produce no air pollutants or greenhouse gases. At the end of 2009, worldwide wind powered generators capacity was 159.2 GW [57]. All wind turbines installed worldwide are generating 340 TWh/year, which is about 2% of worldwide electricity usage. Wind energy is the fastest growing energy source in the world and wind power is one of the most widely used alternative sources of energy today which doubled in the past three years [58].

The potential for wind energy generation in Algeria depends on the availability of the wind resource that varies with location. Understanding the site-specific nature of wind is a crucial step in planning a wind energy project [59] and detailed knowledge of wind on-site is needed to estimate the performance of a wind energy project. The amount of energy produced by a wind turbine depends primarily on the speed of wind but also on the area

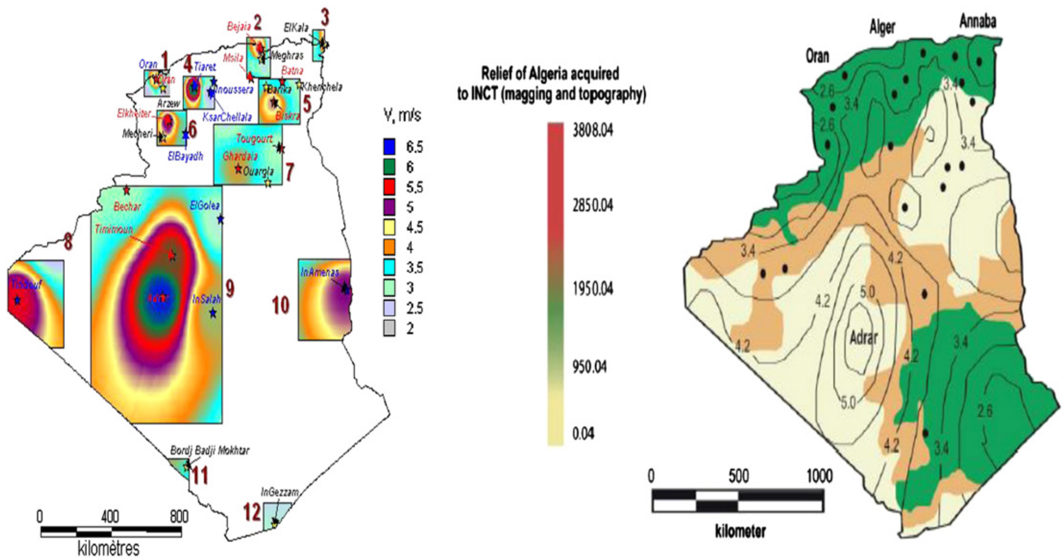


Fig. 9. Wind chart of Algeria. Left: 12 identified windy sites. Right: topography of the identified sites.

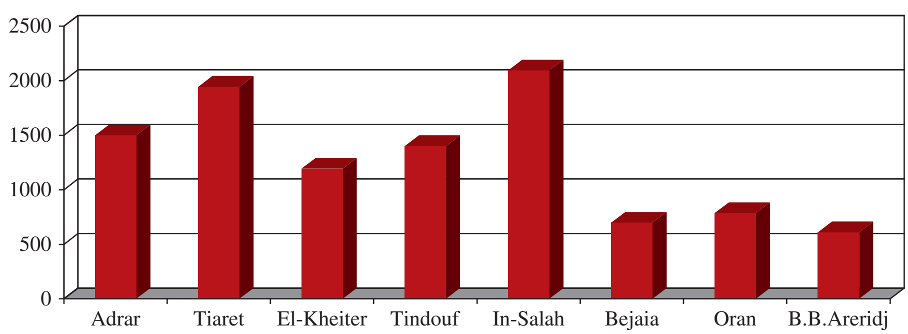


Fig. 10. Average power output in the eight identified windy places.

swept by the blades and the air density. Therefore, a general assessment of the wind energy potential nationwide is needed.

National wind energy potential onshore is rated as low, although the Algerian coastline measures 1200 km. However, in the early 2000s, CDER collected wind data from 75 locations distributed all over Algeria for a 5 year period and the results show that climatic conditions in Algeria are favourable for wind energy utilisation. The wind map of Fig. 9, established by the CDER and MEM [60,61] shows that 50% of the country surface presents a considerable average speed of the wind.

There are a number of promising sites for wind power. They are located in the region of Adrar in the south, Oran in the northwest, the region extending from Meghress to Biskra in the east and the region extending from El Kheiter to Tiaret in the west. A number of sites along the coast have average wind speeds above 5.0 m/s, rising to over 8.5 m/s at 80 m.

The map also shows that the South-Western region experiences high wind speeds for a significant fraction of the year as seen in Fig. 10 showing the annual average power output in these sites [60,62].

This wind energy potential is ideal for the water pumping especially in the high plains. Apart from that, most recent research on potential wind energy in 2010 show that applications involving small wind machines could be used to provide electricity on the relatively undeveloped regions of the great south which are not connected to the national grid [63].

The installation, by Sonelgaz, of nine assessment stations, in different regions of Algeria, where a programme of demonstration is planned, is seen as a second step in stimulating much faster the use of the wind power. The topography and terrain roughness (Fig. 9, right) of these prospective wind sites are also measured and quantified to better simulate and understand the wind flow [64,65]. Offshore data are not available yet.

3.3. PV and wind installations

The MEM and Sonelgaz have created several PV and wind electric systems at remote villages and places that are too far from the main electricity grid to receive power supply. It was a good alternative source of power for villages that would otherwise have to depend on diesel powered generators.

There are 34 approved applications of PV and wind project having a relatively small to medium renewable energy power with total 2.353 MW generation capacity. These installed capacities were mainly oriented towards electrification, water pumping, public lighting and telecommunication. Table 6 lists the distribution of installed power per applications and the distribution of installed power per resources [5].

3.4. Solar and wind current and future realisations

From the last decade, Algeria has achieved relatively heartening developments in the field of solar and wind. These are very appropriate at small-scale power generation for remote area applications. According to the CREG, a short-term strategy for RE electricity supply must be geared to ensure the well-being of its citizens, proper functioning of the economy, and uninterrupted physical availability of energy products on the market, at a price

which is affordable for all consumers while respecting environmental concerns. Overall energy generation of the increasing share of solar and wind energy resources, up to 2017, are given in Table 7 [54].

3.5. Hydroenergy

Hydropower is a mature RE technology which, worldwide, is commercially viable and generates the second largest share of energy from renewable sources. In long term, hydropower stores large amounts of electricity at low cost and can be adjusted to meet consumer demand making important and significant economic contributions to human development. A 19% of the electricity consumed in the world today is generated by hydroelectric power stations. Algeria has a low hydropower electricity generating capacity of about 269.208 MW using 13 dams currently in operation [5]. The share of these small-sized production parks is about 5% which supplements the natural gas production of electricity. Such low capacity is mainly due to the insufficient number of hydraulic sites and to the non-exploitation of existing hydraulic sites.

3.6. Geothermic energy

The Jurassic limestones of North Africa which represent important geothermic reservoirs are at the origin of more than 200 hot springs mainly located in the North-East and the North-West regions of the country. With a multitude of hot springs, Algeria has a large potential for low-temperature geothermal applications. More than 200 geothermal sources were counted by the CDER [37] and are recorded of which one-third's temperatures are superior to 45 °C. These natural outflows which are generally leakages from existing reservoirs have a flow of more than 2 m^3/s of hot water. This represents only a very small part of the production possibilities of the reservoirs.

Deeper in the South, the continental rock formation constitutes a great geothermal reservoir extending over several thousand km^2. This reservoir commonly called the "albian platform" is exploited through drilling, at a flow rate of over 4 m^3/s. This water has an average temperature of 57 °C (Fig. 11). Table 8 shows the different purposes of using the hot water of the albian aquiferous.

The highest temperatures registered are 98 °C in Guelma and 118 °C in Biskra, situated in the South East part of the country. In terms of power production, the internal geothermal energy has been estimated, by CDER, to provide a potential of bout 700 MW (combine the exploitation flow of the albian platform with the total flow from the hot springs). However, these hot springs are unfortunately not exploited for industrial ends. Table 9 depicts characteristics of some hot springs in the North of Algeria.

3.7. Biomass energy

The biomass, in Algeria, is an efficient and friendly way of disposing public waste that is daily collected in large quantities in different cities of the country. A very little work has just started to make biomass usage cost-effective energy source [66]. At present, forest reserves are estimated to be 37,000 ktoe, which is being utilised at a 10% recovery rate. In the North of Algeria, which

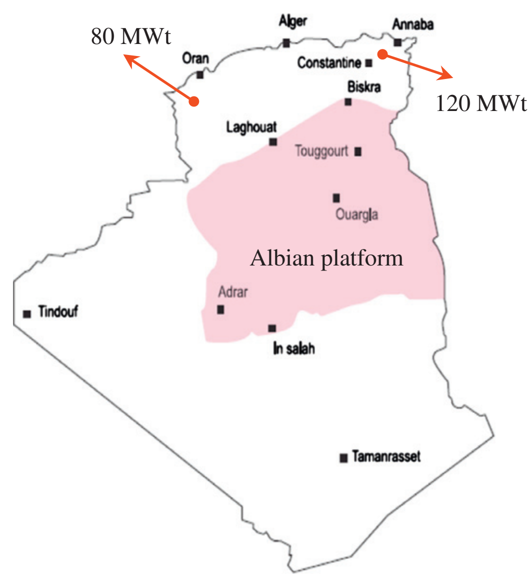


Fig. 11. Albian platform situation.

Table 6
Distribution of installed power per applications and per resources.

Applications	Installed power (W)	Percentage %	PV resource power (W)	Wind resource power (W)
Electrification	1,352,800	57	2,279,960	73,300
Pumping	288,400	13	97%	3%
Public lighting	48,430	2		
Telecommunication	498,000	21		
Others	165,630	7		
Total	**2,353,260**	**100**		

Table 8
Possibilities for using the hot water of the albian aquiferous.

Possible uses	Temperature of water (°C)
Refrigeration (lower limit)	70
Breeding of aquatic animals	60
Mushroom culture, greenhouse heating by aerial pipe	50
Urban heating lower limits	40
Fermentation, greenhouse heating by radiant mulching	30
Fish breeding	20

Table 7
Solar and wind current and future electricity production in MW.
Source: CREG.

Year	2009	2010	2011	2012	2013	2014	2015	2016	2017
Thermal solar		30	30	100	100	100	100	170	170
Wind			10	10	20	20	40	60	80
Cogeneration		50	100	100	150	200	250	300	450
PV	0.51	1.23	1.65	2.21	2.85	3.21	3.8	4.22	5.22
Total	**0.51**	**81.23**	**141.65**	**212.21**	**272.85**	**323.21**	**393.8**	**543.22**	**705.22**

represents 10% of the area of the country or 250,000,000 ha, forests cover 1,800,000 ha and the forest formation deteriorated to scrub around 1,900,000 ha. Maritime pine and eucalyptus, cover only 5% of the Algerian forest, are particularly suitable plants for energy use. In addition, roughly 1330 ktoe of agricultural and municipal residues are available (365 kg per Algerian as urban wastes) [6,43]. Initial work has already began in the areas of utilising biomass energy resource from municipal waste and olive pomace (skins, residues of the pulp and kernels fragments) being a by-product of the olive oil extraction process [67]. However, this work has not yet resulted in power generation and is rather in primary stages as compared with the work on other renewable energy sources [68]. Moreover, the harnessing of organic wastes, mainly animal wastes, for biogas production could be considered as an economic solution. It is decentralised and ecological since it delivers energy autonomy, and allows sustainable development of rural areas. Livestock population in Algeria is presented in Table 10 [43].

4. RE and energy efficiency programme

In view of the increasing energy intensity, the government has emphasised energy efficiency and RE options. Algeria has created a green momentum by launching an ambitious programme to develop RE and promote energy efficiency. This programme leans on a strategy focussed on developing and expanding the use of inexhaustible resources, such as solar energy in order to diversify energy sources and prepares Algeria of tomorrow.

The RE and energy efficiency programme includes the following instruments [69]:

- Capacities to install by field of energy activity.
- Energy efficiency programme.
- Industrial capacities to build in order to back up the programme.
- Research and development (R&D).
- Incentives and regulatory measures.

The programme provides for the development by 2020 of about sixty solar PV and concentrating solar power plants, wind farms as well as hybrid power plants. The projects for the domestic production of electricity from renewable energy sources will be carried out in three phases:

- The first phase, between 2011 and 2013, will be devoted to the achievement of pilot projects to test the different available technologies.
- The second phase (2014–2015) will mark the beginning of the deployment of the programme.
- The third phase, between 2016 and 2020, will be devoted to the large-scale deployment of the programme.

These phases are a part of Algeria's strategy, which is aimed at developing a genuine solar industry along with a training and capitalisation programme that will ultimately enable the use of local engineering and establish efficient know-how, including in the fields of engineering and project management. The renewable energy programme to meet domestic needs in electricity will generate several thousand of direct and indirect jobs.

It is very important to note that the level of natural gas volumes, produced of the domestic market would be 45 billion m^3 in 2020 and 55 billion m^3 in 2030. Other volumes of natural gas are intended for export to help finance national economy. Electricity consumption is expected to reach 75–80 TWh in 2020 and 130–150 TWh in 2030. The massive integration of RE sources in the energy mix represents a major challenge for preserving fossil resources, diversifying electricity production systems and contributing to sustainable development.

4.1. RE programme

Through combining initiatives and the acquisition of knowledge, Algeria is engaged in a new age of sustainable energy use. In its 19-year expansion plan for 2011–2030, the government expects to increase the country's electricity generating capacity by 60% over the next decade. The programme also consists of installing up to 22,000 MW of power generating capacity from renewable sources between 2011 and 2030, of which 12,000 MW will be intended to meet the domestic electricity demand and 10,000 MW destined for export. This last option depends on the availability of a demand that is ensured on the long term by reliable partners as well as on attractive external funding. The total share of RE sources, which are occupying increasingly important places, is expected to increase annually to meet the goal of 40% of electricity production by 2030 as depicted in Fig. 12 [69].

Solar energy is the major focus of the programme of which solar power and photovoltaic systems constitute an essential part. It should achieve, by 2030, more than 37% of national electricity production. Despite its relatively low potential, wind energy is not excluded from the programme as it constitutes the second axis of development with a share in electricity production expected to reach about 3% in 2030 [69]. The share of NG in the production of electricity is expected to drop, mainly due to the participation of RE in the total electricity production.

The country intends to install some experimental size units to test the various technologies in RE such as biomass, geothermal energy and desalination of brackish water.

The RE programme, as planned by MEM, is defined through four different phases:

- Installation of a total power capacity of 110 MW by 2013.
- Installed power capacity to reach 650 MW by 2015.

Table 9
characteristics of some hot springs in the North of Algeria.

Spring and place	Temperature (°C)	Flow rate (l/s)
H. Chellala, Guelma	98	100
H. El Biban, Setif	80	1.2
H. Ben Hachani, Guelma	71.7	0.3
H. Essalihine, Khenchela	70	5
H. Guerfa, Sedrata	68	100
H. Sidi Ayad, Ain timouchent	68	1.2
H. Régha, Méliana	67	–
H. Bouhadjar, Ain timouchent	66.5	–
H. Bouhanifia, Mascara	66	–
H. Salhine, Guelma	55	5

Table 10
Livestock population in Algeria.

Animal	Sheep	Cattle	Goats	Camels	Horses	Mules	Donkeys	**Total**
Number	18,200,000	1,650,000	3,400,000	46,000	154,310	49,690	220.000	23,719,690

- Installed power capacity to reach about 2600 MW by 2020 and a possibility of export of 2000 MW.
- An additional capacity of about 12,000 MW is expected to be installed by 2030 and a possibility of export up to 10,000 MW.

The programme of energy production is summarised and depicted in Fig. 13 [69].

4.1.1. PV solar energy programme

The energy strategy of Algeria is based on the acceleration of the development of solar energy. The government plans launching several solar photovoltaic projects with a total capacity of 800 MWp by 2020. Other projects with an annual capacity of 200 MWp are to be achieved over the 2021–2030 period [31].

PV industrial integration is expected to reach 60% over the period 2011–2013. This ambitious target will be achieved through the construction by “Rouiba-Eclairage”, a subsidiary of the Sonelgaz Group, of a photovoltaic module manufacturing plant with a capacity equivalent to 120 MWp/per year, whose start up is scheduled for late 2013.The period will also be marked by the implementation of measures to strengthen engineering and business development support to the photovoltaic industry through a joint venture that will bring together various stakeholders (Rouiba-Eclairage, Sonelgaz) in partnership with research centres (CDER, the Electricity and Gas Research and Development Centre (CREDEG) and the Silicon Technology Development Unit (UDTS)) [69,70]. The objective of the Algerian industry for the 2014–2020 period is to achieve a capacity integration level of 80% by the construction of a silicon manufacturing plant. Moreover, a national subcontracting network is to be established for the manufacturing of inverters, batteries, transformers, cables and other equipment used in the construction of a PV power plant. There are also plans to develop a centre for the approval of products used in the manufacturing of equipment for RE installations. Over the period 2021–2030, the RE programme aims to reach a rate of integration upper to 80%. Therefore, the production capacity of the PV modules should be expanded to reach 200 MWp/per year. This period would be marked by the development of a national subcontracting network for the manufacturing of equipments necessary for the construction of a PV power plant and by the total control of the activities of engineering, procurement and construction of power plants and brackish water desalination units. There are also plans for the same period to export not only the electricity produced from RE but also the know-how and equipment used in the generation of electricity from these sources [69,71].

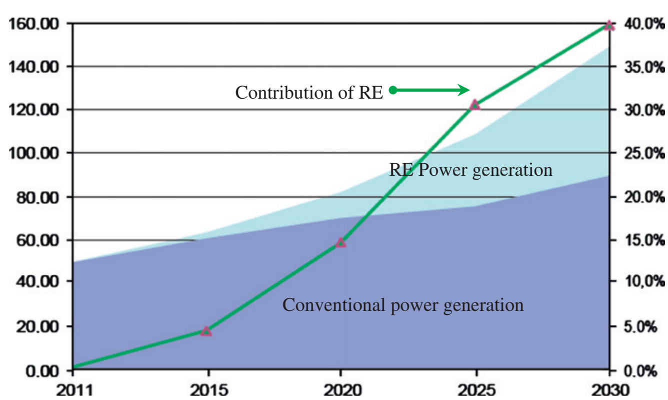


Fig. 12. Contribution of RE for power generation.

4.1.2. Thermal solar energy programme

Algeria seeks to develop its solar potential, which is one of the most important in the world, by launching major projects in solar thermal. Pilot projects for the construction of two solar power plants with storage of a total capacity of about 150 MW each, will be launched during the 2011–2013 period. These will be in addition to the hybrid power plant project of Hassi R’Mel with a total power capacity of 150 MW, including 25 MW in solar. Four solar thermal power plants with a total capacity of about 1200 MW are to be constructed over the period 2016–2020. The 2021–2030 plan to tap its large solar potential is to provide the installation of an annual capacity of 500 MW until 2023, then 600 MW per year until 2030 [31]. Moreover, the 2011–2013 period will also see the launching of studies for the local manufacturing of equipment for the solar thermal sector. The industrial integration rate is expected to reach 50% over the 2014–2020 period through the implementation of four major projects in parallel with actions for engineering capacity building that are [69,72]:

- Construction of a mirror manufacturing plant.
- Construction of heat transfer fluid and energy storage equipment factories.
- Construction of a factory for the manufacture of power block equipment.
- Development of engineering activities and design, procurement and production capabilities to achieve an industrial integration capacity rate of at least 50%.

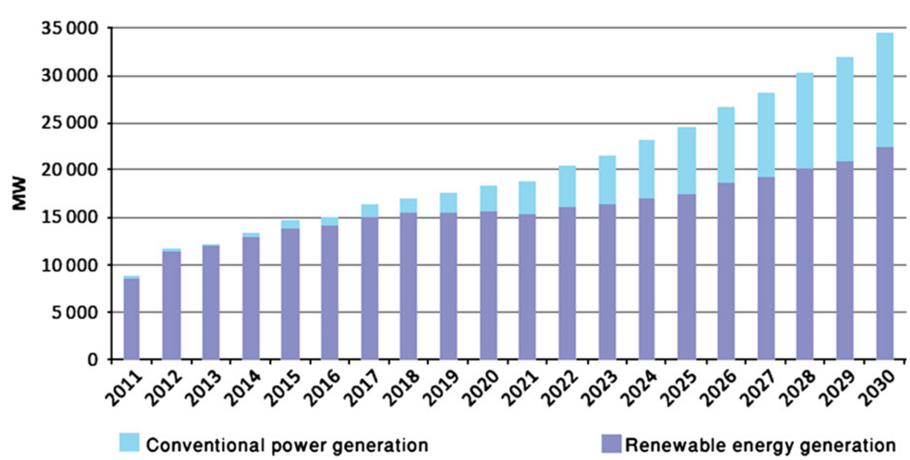


Fig. 13. Structure of the national power generation in MW.

In addition, the rate of integration, over the 2021–2030 period, should exceed 80% through the implementation of the following projects:

- Expansion of mirror production capacity.
- Expansion of heat transfer fluid and energy storage equipment production capacity.
- Expansion of power block equipment production capacity.
- Design, procurement and construction of power plants by own means.

4.1.3. Wind energy programme

Algeria has set a programme plans at first, in the period 2011–2013, the installation of the first wind farm of a power of 10 MW in Adrar. Between 2014 and 2015, two wind farms with a capacity of 20 MW each are to be developed. Studies, by Sonelgaz, will be led to detect suitable sites to realise the remaining planned projects during the period 2016–2030 for a total goal power of about 1,700 MW. Studies are to be launched by 2013 with a view to implement wind energy industry. The objective for the 2014–2020 period is to attain an integration rate of 50%. This period will be marked by the following actions [69]:

- Development of a wind tower and turbine rotors production plant.
- Promotion of a national subtracting network for the manufacturing of the nacelle equipment.
- Development of engineering activities and design, procurement and construction capabilities to enable Algerian companies to achieve an industrial integration capacity rate of at least 50%.

The rate of industrial integration is to exceed 80% over the 2021–2030 period with the expansion of wind tower and turbine rotors production capacity and the development of a national subcontracting network for manufacturing the nacelle equipment. There are also plans to design and build wind farms, power plants and brackish water desalination plants using Algeria's own resources.

The RE related legislation has been intensified. The cornerstone of Algeria's legislation on electricity from renewable sources is the law on the utilisation of RE resources for the purpose of generating electricity, enacted in August 2004. Also relevant are several related laws [73]. Together laws also include the following instruments:

- to guarantee the electrical power supply for all of the inhabitants of the country;
- to foment conservation and efficiency in energy use;
- to respect the environment;
- to progress towards energy diversification;
- to improve regional infrastructures related to energy generation, transportation, and distribution;
- to raise awareness in the population regarding the use of RE sources.

4.2. Energy efficiency programme

In 2003, the public authorities adopted the national energy efficiency policy, hence ordaining the implementation of the law of July 1999 relating to energy efficiency. The implementation mechanism for this strategy is constituted of four instruments defined within the framework of this law, namely the National Energy Efficiency Programme (NEEP), the National Energy Efficiency Fund (NEEF), the Inter-Sector Energy Efficiency Committee (ISEEC) and the APRUE, a mechanism to be reinforced by an incentive price policy and appropriate regulations. The NEEF was created with the objective of financing energy efficiency investments as well as the budget of the APRUE and the projects it manages under the PNME.

APRUE is the central element of the mechanism to implement this strategy. It is also responsible for the information, communication and management training missions of all the public players involved in energy efficiency and particularly the establishment of partnerships in order to draw up together transversal or sector action programmes, falling within the framework of the NEEP and which may potentially benefit from the financial incentives of the NEEF.

4.2.1. Energy efficiency programme components

The energy efficiency programme is governed by Algeria's aiming to promote a more effective manner to use energy and to investigate all the ways to protect its energy resources by an efficient and optimal consumption. To meet this target, the current energy efficiency programme of the MEM relies on the following [31]:

- *Improving heat insulation of buildings*: The construction sector uses more than 42% of overall energy consumption. Proposed measures to achieve energy efficiency in this sector include the introduction of thermal insulation of buildings, which will reduce energy consumption related to home heating and cooling by about 40%.
- *Developing solar water heating*: The penetration of solar water heaters in Algeria remains undeveloped but the potential is significant. There are plans to develop the solar water heating system to gradually replace the conventional system. The plans are and included in the ministry portfolio and supported by the NEEF.
- *Spreading the use of low energy consumption lamps*: The objective of the action strategy is to gradually prohibit the marketing of incandescent lamps (conventional lamps commonly used by households) on the domestic market to reach a total ban by 2020. In parallel, there are plans to put several million low-energy bulbs on the market. Furthermore, local production of low consumption lamps will be encouraged in particular through partnerships between local and foreign producers.
- *Introducing energy performance in street lighting*: Street lighting is the most energy consuming sector in the municipalities. These latter's officers are often poorly informed about the opportunities for improving and even reducing energy consumption in public lighting. The programme for energy efficiency in the municipalities consists of replacing all mercury (energy consuming) lamps by sodium (low energy) lamps.
- *Promoting energy efficiency in the industrial sector*: The industrial sector accounts for about one fourth of the country's overall energy consumption. For more energy efficiency, there are plans for:
  - cofinancing energy audits and feasibility studies that will enable companies to precisely define technical and economical solutions best suited for reducing energy consumption;
  - cofinancing additional costs linked to the introduction of energy efficiency into technically and economically viable projects.
- *Promoting Liquefied Petroleum Gas (LPG) and NG fuels*: There are plans to increase by 20% the market share of LPG fuel in the automobile fleet by 2020.This will be accompanied by the provision of direct financial assistance to individuals wishing

to convert their vehicles to LPG fuel. As early as the beginning of the 1990s, a research programme was initiated to convert vehicles using diesel fuel to natural gas fuel. Stations were developed by Sonelgaz for the distribution of this fuel to an experimental fleet. By 2013, it is planned to put on in NG fuel several tens of bus in the city of Algiers and to extend the operation to the other big cities of Algeria, like Oran and Constantine, before 2020.

- *Developing solar cooling systems*: Solar energy for air conditioning is a technology that should be promoted particularly in the south of the country, as far as the needs for cooling mostly coincide with the availability of solar radiation (conversion of sunrays into energy). Moreover, solar collectors may also be used for hot water production and room heating during the cold season. The overall performance of a solar cooling system is therefore of a great interest. By 2013, studies will be launched to acquire and harness solar cooling technologies and choose the system best suited to the Algerian context. Two pilot projects for air cooling using absorption and adsorption chillers will be launched for the cooling of buildings in the south of the country.
- Promoting co-generation.
- Conversing simple cycle power plants to combined cycle power plants, wherever possible.
- Desalinating brackish water using RE.

5. Clean development mechanism in Algeria

With the expansion of the Energy and Mining sector and the availability to the population and industry of energy products on a large scale, considerable efforts are needed to prevent the damaging of the environment and the quality of life in general. In fact, the Energy and Mining sector attaches a great importance to issues related to the protection of the environment and public health. The integration of these concerns in the sector policy is based on the facet "energy and mines policy" of the governmental programme. This resulted in the implementation of measures essentially linked to the following objectives [29]:

- the promotion and the development of the use of least polluting fossil fuels (NG, LPG, unleaded gasoline);
- the promotion of energy savings;
- the rehabilitation of polluted sites;
- the development of renewable energies;
- the development of the environmental management at the level of the Energy and Mining sector.

The sector of energy reforms in the process of implementation assigns an important place to the environment; special provisions are thus introduced by the new laws on Mining and Electricity production. The carrying out of impact studies on environment; the implementation of environment management plans and the auditing on the complexes with respect to environment are made obligatory by the sector and also under its responsibility.

The integration of the environment protection and the sustainable development within the formulation of the policy, planning and management is imperative to the sector given the necessity of protecting natural habitats, public health and also the commitment of the country relative to the international legal instruments and to different agreements and conventions entered into the country.

The main emitters of GHG are fuel combustion in the energy sector, in industry, and in the transport sector. Other important contributors are agriculture, small combustion, non-combustion emissions in industry and waste. The structure of the Algerian primary energy supply is very favourable with respect to GHG emissions which amount to about 84 million of tons/year (2.53 t/person/year) as shown in Fig. 14 [74–77].

Comparing with other countries, Algeria's contribution to global climate change is very small and up to now, Algeria meets all the requirements of signed international conventions in the field of atmospheric pollution. Algeria is also involved in the carbon capture and storage (CCS) technology, with one of the very few functioning projects in the world.

The gas from the In Salah field has a high CO_2 concentration, which needs to be decreased to reach pipeline specifications. After removal, instead of being released into the atmosphere, the CO_2 is re-injected into an aquifer that is part of the same geological formation as the gas field. Today, the In Salah Gas plant is in full operation. Produced CO_2 from the natural gas stream is removed in the desert processing plant and is being sequestered into underground storage at an injection rate of 1.3 million of tonnes/year. Close monitoring for performance is being made on this large operation by Sonatrach, BP and Statoil [78,79]. These same firms are also developing the In Amenas gas condensate field which lies close to the Libyan border [80,81].

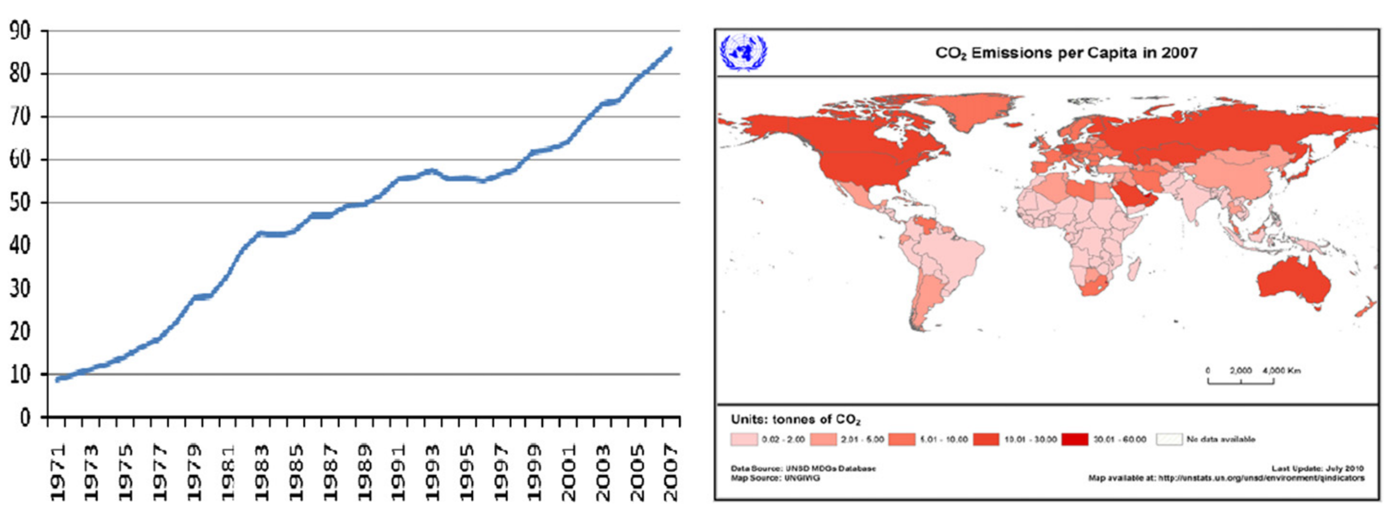


Fig. 14. Algerian CO_2 energy related emission in million of tons.

6. Conclusion and recommendations

Algeria energy sector is still heavily dependent on non-renewable fuel such as crude oil and NG as a source of energy. Recently increased environmental awareness and energy security interest, resulting from parliament and government debate over after oil period, have encouraged interest in the integration of large scale RE into the energy mix. RE, including wind power, solar technologies and new forms of biomass, have been receiving government support to reach sustainability. Algeria has also made substantial progress on the regulatory side to promote RE production. The long term plan to tap its large potential for renewables is included in the RE and energy efficiency programme proposed by the MEM and adopted, on February 3, 2011, by the government headed by the president Abdelaziz Bouteflika who stated that the promotion of RE has to be the clear target for the country and that environmental issues need to be addressed. Algeria has ambitious quantitative targets to generate at least 40% electricity from RE by 2030, an encouraging energy strategy. Making solar/ wind energies a complementary source to hydrocarbons is an intermediate solution for Algeria before the total exhaustion of conventional resources. The energetic diversity is certainly the worldwide means to make the best of an energy economy which is imposed, seen the situation. Solar energy is indeed a clear alternative to grid electrification in Algeria, it is only through strong mechanisms of information, staff training and social acceptance that it can be utilised to its full capacity.

References

[1] Muneer T, Asif M, Munawwar S. Sustainable production of solar electricity with particular reference to the Indian economy. Renewable and Sustainable Energy Reviews 2005;9:444–73.
[2] British Petroleum. BP Statistical review of world energy. British: BP Plc.; 2008.
[3] International Energy Agency Report, ⟨www.iea.org/⟩; 2010.
[4] Trieb F, Schillings C, O'Sullivan M, Pregger T, Hoyer-Klick C. Global potential of concentrating solar power. German Aerospace Centre (DLR); 2009.
[5] Ministry of Energy & Mines, ⟨http://www.mem-algeria.org⟩; 2011.
[6] StambouliA. Boudghene. Survey report on renewable energy manufacturing facilities in Algeria. United Nations, Index 382958; 2007.
[7] Algeria Moves to Develop Oil and Gas Reserves, stock analysis of 2010, ⟨http://stocks.investopedia.com/⟩; 2010.
[8] Oil and Gas Journal, International Petroleum News and Technology, ⟨http://www.ogj.com/⟩; September 2011.
[9] Mahmoudi H, Ouagued A, Ghaffour N. Capacity building strategies and policy for desalination using renewable energies in Algeria. Renewable and Sustainable Energy Reviews 2009;13(4):921–6.
[10] Himri Y, Stambouli ABoudghene, Draoui B. Prospect of wind farm development in Algeria. Desalination (Elsevier) 2009;239:130–8.
[11] The Future of Algeria Oil and Gas Industry to 2020—forecasts of supply, demand, investment, companies and infrastructure (fields, blocks, pipelines, LNG, refinery, storage assets). Published By OG Analysis; 2/3/2011. Report Code: OG Analysis1002; 2011.
[12] Algerian Drilling Update, ⟨http://www.gulfoilandgas.com/⟩; 2009.
[13] Algeria energy report, ⟨http://endofcrudeoil.blogspot.com/2012/03/algeria-energy-report.html⟩; 2012.
[14] Cherigui A, Mahmah B, Belhamel M, Chader S, M'Raoui A, Harouadi F, et al. Solar hydrogen energy: the European/Maghreb connection a new way of excellence for a sustainable energy development. Revue des Energies Renouvelables 2007;10(4):589–96.
[15] Market Research reports, ⟨www.marketresearch.com⟩; 2011.
[16] Alternative energy Africa, ⟨http://ae-africa.com/magazine.php⟩.
[17] Sonatrach-Group, ⟨www.sonatrach-dz.com⟩; 2012.
[18] Market Research News, ⟨http://www.salisonline.org/market-research/top-ten-african-power-market-outlook-to-2020/⟩; 2011.
[19] Energie & Mines. Review of the energy and mining sector; January 2012.
[20] Policy DB Details: Algeria (2010), Renewable Energy & Energy Efficiency Partnership (REEP) annual report (2010–2011), ⟨http://www.reeep.org/⟩.
[21] Algeria energy market report, ⟨http://www.enerdata.net⟩; updated November 2011.
[22] Sonelgaz, ⟨http://www.sonelgaz.dz⟩; 2010.
[23] Clean technology fund investment plan for CSP in the MENA region. Intersessional Meeting of the CTF Trust Fund Committee of the world bank. Washington, DC; December 1–2, 2009.
[24] Algeria Seeks Alternatives to Hydrocarbon Economy, ⟨www.magharebia.com⟩; 2011.
[25] World Bank. 2009 Report; 2009.
[26] Office National des Statistiques, ONS, Algeria, ⟨http://www.ons.dz/⟩; 2009.
[27] Algerian Energy Company report, ⟨http://www.aec.dz⟩; 2010.
[28] ICIS Heren. Algerian power exports hinge on renewable. Report of 16 February 2011, ⟨http://www.icis.com/heren/articles/2011/02/16/9436028/algerian-power-exports-hinge-on-renewables.htmlx⟩; 2011.
[29] Stambouli ABoudghene. Promotion of renewable energies in Algeria: strategies and perspectives. Renewable and Sustainable Energy Reviews 2011;15:1169–81.
[30] The Titi Tudorancea bulletin, ⟨http://www.tititudorancea.com/⟩; 2010.
[31] Ministry of Energy and Mines and Sonelgaz Group Company; March 2011.
[32] Bloomberg. New Energy Finance, ⟨http://bnef.com⟩.
[33] Stambouli ABoudghene, Koinuma H. A primary study on a long-term vision and strategy for the realisation and the development of the Sahara Solar Breeder project in Algeria. Renewable and Sustainable Energy Reviews 2012;16:591–8.
[34] International Energy Agency Report, ⟨www.iea.org⟩; 2011.
[35] Jacobson MZ. Review of solutions to global warming, air pollution, and energy security. Energy & Environmental Science 2009;2(2):148–73.
[36] World Energy Council, ⟨www.worldenergy.org⟩; 2011.
[37] CDER Algeria, ⟨http://www.cder.dz⟩.
[38] Stambouli ABoudghene. Algerian renewable energy assessment: the challenge of sustainability. Energy Policy 2011;39:4507–19.
[39] Steinhagen H. Muller. Renewable energies in the MENA region: potential for sustainable energy provision and export to Europe. Institute of Technical Thermodynamics German Aerospace Centre (DLR, 2010); 2010.
[40] PVGIS Solar Map, ⟨http://www.rensmart.com/Weather/PVGISSolar⟩; 2010.
[41] German Aerospace Centre (DLR), ⟨www.dlr.de⟩; 2005.
[42] Himri Y, Arif Malik S, Stambouli ABoudghene, Himri S, Draoui B. Review and use of the Algerian renewable energies for sustainable development. Renewable and Sustainable Energy Reviews 2009;13(6–7):1584–91.
[43] Energy & Mines Book, ⟨http://www.mem-algeria.org⟩; 2007.
[44] Koinuma H, Kanazawa I, Karaki H, Kitazawa K. SCJ proposal at the G8+5 Academies. Meeting. Rome; March 26, 2009.
[45] Bullis K Solar thermal plants losing out to photovoltaics, ⟨http://www.technologyreview.com/blog/energy/26961/⟩; 2011.
[46] ⟨http://www.blythesolarpower.com/⟩.
[47] ⟨http://news.cnet.com/8301-11128_3-20076065-54/solar-thermal-plants-scrap-steam-for-photovoltaic/⟩.
[48] ⟨http://www.pv-tech.org/news/⟩.
[49] Sahara Solar Breeder Foundation Official Website, ⟨http://www.ssb-foundation.com⟩.
[50] Centrotherm photovoltaics AG/ Kinetics Germany GmbH consortium signs major order to construct fully integrated factory in Algeria, ⟨http://www.renewable-energy-sources.com/2011/05/02/⟩.
[51] Centrotherm Photovoltaics, Kinetics Germany to build factory in Algeria, ⟨http://www.algeria.com/forums/business-affaires/19030-22.htm⟩.
[52] Kurokawa K, Keiichi K, Masakazu I, Peter V. In: Van Der David F, editor. Energy from the desert—III: IEA-PVPS task-8 report. UK: James & James Ltd.; 2009.
[53] Energie & Mines, review of the energy and mining sector. No. 03; November 2004.
[54] CREG 2008, Commission de Régulation de l'Electricité et du Gaz. Programme indicatif des besoins en moyens de production d'électricité 2008–2017, ⟨www.creg.gov.dz/⟩.
[55] Algeria—a future supplier of electricity from RE to Europe? Algeria's perspective and European approaches. A report by Wuppertal Institute for Climate. Environment and Energy and Centre de Recherche en Economie Appliquée pour le développement (CREAD); 1 August 2010.
[56] Characterisation of solar electricity import corridors from MENA to Europe. Stuttgart, DLR: German Aerospace Centre; 2009.
[57] WWEA (World Wind Energy Association). World wind energy report 2009. Bonn, Germany; 2009.
[58] Leung DYC, Yang Y. Wind energy development and its environmental impact: a review. Renewable and Sustainable Energy Reviews 2012;16(1):1031–9.
[59] EIB. Wind energy, ⟨http://eib.org.my/index.php?page=article&item=100,136,144⟩; 2010.
[60] Kasbadji N. Wind energy assessment in Algeria. In: Proceedings of the international workshop on physics and renewable energies. El-Oued, Algeria: 2010. p. 28–32.
[61] Himri Y, Rehman S, Agus Setiawan A, Himri S. Wind energy for rural areas of Algeria. Renewable and Sustainable Energy Reviews 2012;16(5):2381–5.
[62] Himri Y, Stambouli ABoudghene, Draoui B, Himri S. Wind power resource in the south-western region of Algeria. Renewable and Sustainable Energy Reviews 2010;14:554–6.
[63] Chellali F, Khellaf A, Belouchrani A, Khanniche R. A comparison between wind speed distributions derived from the maximum entropy principle and Weibull distribution. Case of study; six regions of Algeria. Renewable and Sustainable Energy Reviews 2012;16(1):379–85.
[64] Himri Y, Stambouli ABoudghene, Draoui B. Assessing the wind energy potential projects in Algeria. Renewable and Sustainable Energy Reviews 2009;13:2187–91.
[65] MEM , ⟨http://www.mem-algeria.org/fr/enr/carte_vents.htm⟩; 2005.
[66] Kherbouche D, Bernhard-Reversat F, Moali A, Lavelle P. The effect of crops and farming practices on earthworm communities in Soummam valley, Algeria. European Journal of Soil Biology 2012;48:17–23.
[67] Salem Z, Lebik H, Cherafa WK, Allia K. Valorisation of olive pits using biological denitrification. Desalination 2007;204(1–3, Special Issue):72–8.
[68] Energy Information Administration, ⟨http://www.eia.gov/cabs/Algeria/pdf⟩.
[69] Renewable Energy and Energy Efficiency Program, MEM. Portail des énergies renouvelables. CDER, ⟨www.cder.dz⟩; 2011.

[70] Unité de Développement des Technologies du Silicium (UDTS), 〈www.udts.dz〉.
[71] Yamani N, Mohammedi K, Khellaf A. Le potentiel solaire algérien figure parmi l'un des plus importants au monde, 〈http://portail.cder.dz/spip.php?article2141〉.
[72] Bulletin des Energies Renouvelables, No. 23. EISSN/ISSN 1112-3850, 〈www.cder.dz/bulletin/〉; 2012.
[73] Journal Officiel de la République Algérienne, 〈http://www.mf.gov.dz/〉.
[74] IEA Press, 〈http://www.iea.org〉; June 2008.
[75] US environmental protection Agency, 〈http://epa.gov/climatechange/〉.
[76] United Nations Statistics, 〈http://unstats.un.org/unsd/environment/air_co2_emissions.htm.
[77] 〈http://www.carbonplanet.com/country_emissions〉.
[78] Driscoll J, Benyoub S and Riddiford F. International conference on integrated sustainable energy resources in arid regions, Sub: Environment 2007. CO_2 Sequestration in the In Salah Gas Project. Abu-Dhabi, UAE: 2007.
[79] Ramakrishna R. An analysis of energy consumption and carbon dioxide emissions in countries of the Middle East and North Africa. Energy 2005;30(15):2831–42.
[80] BP Sustainability Review, bp.com/sustainability; 2010.
[81] Algeria Energy Situation, 〈https://energypedia.info/〉; 2011.